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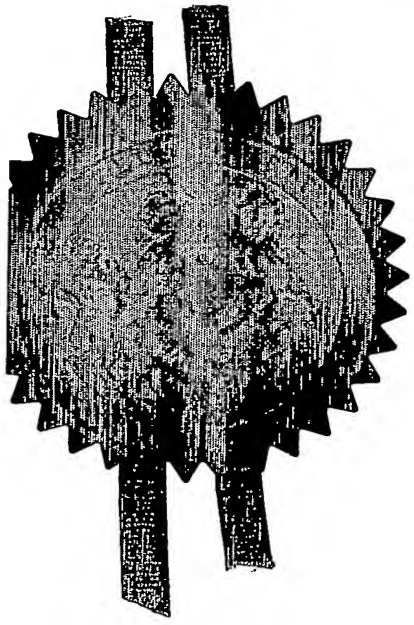

Signed Andrew Gregg

Dated 16 December 2003

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P01/7700 0.00-0310021.1

Request for grant of a patent

1. Your reference	SJW/37453.GBA1
2. Patent application number	0310021.1
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	Magnesium Elektron Limited The Victoria, Harbour City, Salford Quays, Manchester M5 2SP
Patents ADP number	58245203
If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom
4. Title of the invention	COMPOSITE SACRIFICIAL ANODES
5. Name of your agent *(if you have one)*	Raworth Moss & Cook
"Address for service" in the United Kingdom to which all correspondence should be sent	Raworth House 36 Sydenham Road, Croydon, CR0 2EF
Patents ADP number	1362001

- 1 MAY 2003

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number	Date of filing

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer yes if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant
c) any named applicant is a corporate body

YES

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9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document.

Continuation sheets of this form	-
Description	8
Claim(s)	4
Abstract	
Drawing(s)	2

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application

Signature

Date 1st May, 2003

12. Name and daytime telephone number of person to contact in the United Kingdom

Raworth Moss & Cook, Stephen J. Wise
020 8688 8318

COMPOSITE SACRIFICIAL ANODES

The invention relates to composite sacrificial anodes, particularly but not exclusively, based on magnesium, and to methods for their production.

Magnesium or magnesium alloy sacrificial anodes have been used for many years to provide cathodic corrosion protection for iron and steel engineering products, particularly in the oil industry. This technique is used to protect pipelines, marine oil installations, ships and other large steel constructions.

The corrosion protection provided by the anode can be measured in two ways: the potential (voltage) of the anode, and the output capacity of the anode measured as amp-hours per kilogram of the sacrificial magnesium alloy.

There are at present three commonly used magnesium alloys that meet ASTM B843-93, namely (a) magnesium with 0.5-1.3% by weight manganese which produces a voltage of 1.7V, (b) magnesium with 5.3-6.7% by weight aluminium, 2.5-3.5% by weight zinc and 0.15-0.7% by weight manganese, and (c) magnesium with 2.5-3.5% by weight aluminium, 0.6-1.4% by weight zinc and 0.2-1.0% by weight manganese, both (b) and (c) producing a voltage of 1.5V.

The output capacity is affected by both the alloy used and by the method of manufacture of the anode. In particular, the cooling rate of the metal during solidification has been found to be important. (Juarez-Islas et.al 1993). The theoretical value for the output capacity for magnesium alloys is 2400 Ahr/kg. However it

is reported that typical anodes are only 30-35% efficient.

Currently, 'D' shaped magnesium anodes of the type shown in accompanying Fig 1 are manufactured by casting magnesium alloys around a steel insert laid horizontally in an open top permanent mould, usually manufactured of cast iron. The insert provides both the mechanical and the electrical connection between the anode and the structure being protected. This method of manufacture typically results in a variable metal cooling rate both within individual anodes, and between anodes within a batch. In the case of large anodes, i.e. greater than 10 kg, or very large anodes i.e. greater than 100 kg, for example in the region of 5 tonnes, the solidification rate in the centre of the anode will be substantially lower than that at the edge. This results in the electrochemical efficiency of conventional anodes being both poor and variable.

This invention relates to sacrificial anodes, particularly of magnesium or a magnesium alloy, which have improved performance with respect to output capacity, especially for large and very large anodes.

This is achieved by effectively dividing up a large anode into smaller parts, each of which is produced under carefully controlled conditions and is arranged to function on its own, but together the parts behave as a single anode. The parts must be joined together in such a way that their erosion takes place essentially only on their outermost exposed surfaces. In particular it should be ensured that there is no premature erosion of the sacrificial material in the region of its electrical connection before the material remote from the connection

has been eroded, particularly when the electrical connection is offset in the material.

The anodes of the present invention are intended to be connected to the structure to be protected indirectly through their electrical connection without the sacrificial material of the anodes needing to be in direct contact with the structure.

In accordance with the present invention there is provided a composite sacrificial anode comprising a plurality of castings of a sacrificial material each disposed around a corresponding electrical connector for attachment to a structure to be protected, wherein each electrical connector extends into its corresponding casting in the casting direction; wherein the castings are connected electrically together by their respective electrical connectors being joined, and wherein the sacrificial material of each casting is protected from external erosion in the region of its attachment to its connector. By being connected via their electrical connectors, each casting can be considered as a part or segment of a large composite anode.

The present invention also provides a method of producing a composite sacrificial anode having an electrical connection for attachment to the structure to be protected, which method comprises casting a plurality of segments of the sacrificial material each in contact with a corresponding electrical connector, each connector being at least partly within its corresponding individual segment and aligned in the casting direction, and joining the individual electrical connectors together to provide the said electrical connection, wherein each segment is

protected from erosion around its exposed electrical connector.

Each electrical connector is preferably substantially straight and fully aligned with the casting direction, although some deviation is possible. Each connector is generally smooth, although some roughening, ridges, grooves and the like may be helpful for arranging good electrical and physical connection with the sacrificial material. An individual connector may take the form of a plurality of separate connectors embedded in the same casting.

In one embodiment a waterproof mastic or resin is used to coat the surfaces of the segments around their exposed connectors, when the connectors are on or near the surface of the segments. Preferably each segment is identical and is assembled together with the other segments to form a composite anode in the form of a block, with any gaps between the segments being filled with an electrically insulating waterproof mastic or resin. Such a composite anode may be cylindrical, square, rectangular or segmental in cross-section. Conveniently in such an arrangement the individual connectors are cast in an off-centre position; so that when assembled together the connectors are close together for easier joining. In order to avoid premature erosion of the sacrificial material in the region of each offset connection, the surface of the material in the region of each connector is coated with the mastic or resin.

By providing each of the segments with its own electrical conductor and by arranging for those individual electrical conductors to be joined, an electrical pathway between each anode segment and the structure to be

protected is ensured throughout the erosion life of each segment. Additional electrical connections can be provided between the different segments, such as by strapping them together with one or more metal bands, but any such additional electrical connections must not allow the formation of voids between the segments into which water could ingress during the erosion of the composite anode. The waterproof mastic or resin must therefore fill any gaps, preferably totally, between these segments so that even when segments are well eroded their further erosion continues to take place essentially only on their outermost surfaces and not between them. Generally an electrically insulating mastic or resin is used, such as pitch or a polyurethane, or for some arrangements of segments it may be preferred to use an electrically conductive resin such as a styrene-isoprene rubber in which an electrically conducted material such as graphite or carbon black has been incorporated as a filler.

In the most preferred embodiment of the present invention each segment, of preferably a magnesium or magnesium alloy, is cast using direct chill (DC) casting technology. This is a method of manufacture currently used to produce magnesium slabs or billets as described in, for example, Grandfield, J. and McGlade, P. "DC Casting of Aluminium: Process Behaviour Magnesium Technology", Materials Forum Australia, Volume 20, 1996, p. 29-51. The preferred embodiment of the invention is a modification of this known production method to allow for the introduction of a steel insert into the cast magnesium or magnesium alloy billet or slab so as to produce an anode. This is shown schematically in Fig. 2, the insert being positioned off-centre near one of the walls of the mould and aligned with the casting direction.

Each off-centre insert, which is preferably a galvanised straight smooth mild steel bar, protrudes from its respective casting so that when the segments of the composite anode are assembled together their respective inserts can be joined together to provide both a mechanical and an electrical connection to the structure to be protected. Generally the protruding ends of the inserts are welded together and joined to a main connector, such as a cable clamp, which is integral with or else attached to the inserts, for example by welding, so as to provide the electrical connection to the structure to be protected.

A square cross-section anode made up of four continuously cast segments with a welded cable connector attached to its insert is shown in Fig 3. This insert is made up of the four off-centre bars of the four segments close together but not touching along their lengths inside the anode. Each bar preferably extends through the whole length of its respective segment and is joined at each end to the other three bars where they are exposed or protrude from their segments by welding.

To one of the welded junctions the cable connector is welded, and at both ends of the composite insert the welded junctions are covered by the mastic with only the cable connector exposed. An electrical wire or cable is then attached to the exposed cable conductor for connecting the composite anode to the structure to be protected.

This method of production enables a uniform, controllable and rapid cooling rate to be applied to each segment by directly cooling with a water spray. This results in an

improved electrochemical efficiency for the composite anode over a permanent mould cast anode of the same size.

Table 1 sets out the typical output capacity from a conventionally cast anode compared to that from an anode produced by DC casting.

Anode type	Energy capability(Ahr/Kg)
Conventionally Cast	1000
DC cast	1700

Table 1. Typical energy capability of conventionally vs. DC cast anodes.

The present invention is particularly suitable for fabricating very large anodes, e.g. in the region of 5 tonnes. By combining two or more anode sections together the composite behaves as one large anode. The sections used in the composite may be produced by DC casting or by conventional permanent mould casting. In either case, the fabricated anode produces an improved electrochemical efficiency over a single permanent mould cast anode of the same size since the cooling and solidification rates of the individual segments are faster and more controlled than would be the case if the anode were cast in one piece.

In a second embodiment, the requisite protection of the sacrificial material in the region of its electrical connector is provided by the sacrificial material itself. In this embodiment each connector is not offset, but extends substantially to the centre of its corresponding casting. Since erosion of the sacrificial material is uniform towards its centre there is no need for any

surface protection of the sacrificial material in this embodiment.

The present invention thus also provides a sacrificial anode assembly comprising a plurality of castings of a sacrificial material each disposed around a protruding electrical connector for attachment to the structure to be protected, wherein the castings are connected electrically together by their respective electrical connectors being joined to a common electrical connection to the structure to be protected, and wherein each connector extends in the casting direction substantially to the centre of its casting.

Preferably each connector is straight and extends to the centre of each casting, and may go right through to provide, for example, some anchorage for the casting or physical connection to one or more other castings. The castings can be unattached to one or more of the other castings - apart from their electrical connection - or can be physically connected to one or more of them.

Preferably the assembly comprises between two and six segments joined together by a waterproof mastic or resin to provide a composite anode which acts as a single anode.

The preferred composite anode consists of two to four segments together with the gaps completely filled with a waterproof mastic or resin as shown schematically in Fig 3. The inserts of each segment are linked together and sealed using preferably pitch. This causes the composite anode to corrode from the outside only, and hence provides the voltage and current flow equivalent to a single block.

CLAIMS

1. A composite sacrificial anode comprising a plurality of castings of a sacrificial material each disposed around a corresponding electrical connector for attachment to a structure to be protected, wherein each electrical connector extends into its corresponding casting in the casting direction; wherein the castings are connected electrically together by their respective electrical connectors being joined, and wherein the sacrificial material of each casting is protected from external erosion in the region of its attachment to its connector.

2. An anode as claimed in claim 1 wherein the castings are joined together by a waterproof mastic or resin.

3. An anode as claimed in claim 2 wherein the waterproof mastic or resin coats the surface of each casting around its electrical connector.

4. An anode as claimed in any one of claims 1 to 3 wherein each electrical connector is substantially straight.

5. An anode as claimed in any one of claims 1 to 4 wherein the mastic or resin completely fills any gaps between the castings.

6. An anode as claimed in any one of claims 1 to 5 wherein the castings are identical.

7. An anode as claimed in any one of claims 1 to 6 wherein the sacrificial material is magnesium or a magnesium alloy.

8. An anode as claimed in claim 7 wherein the sacrificial material is an alloy consisting essentially of magnesium and from 0.15 to 1.3% by weight of manganese.

9. A sacrificial anode assembly comprising a plurality of castings of a sacrificial material each disposed around a protruding electrical connector for attachment to the structure to be protected, wherein the castings are connected electrically together by their respective electrical connectors being joined to a common electrical connection to the structure to be protected, and wherein each connector extends in the casting direction to the centre of its casting.

10. An assembly as claimed in claim 9 wherein the castings are identical and are formed by direct chill casting.

11. An anode as claimed in claim 1 substantially as hereinbefore described.

12. An anode as claimed in claim 1 substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

13. A method of producing a composite sacrificial anode having an electrical connection for attachment to the structure to be protected, which method comprises casting a plurality of segments of the sacrificial material each in contact with a corresponding electrical connector, each connector being at least partly within its corresponding individual segment and aligned in the casting direction, and joining the individual electrical connectors together to provide the said electrical

connection, wherein each segment is protected from erosion around its exposed electrical connector.

14. A method as claimed in claim 13 wherein a waterproof mastic or resin is arranged to coat the surfaces of the segments around their exposed connectors.

15. A method as claimed in claim 13 or claim 14 wherein each electrical connector is substantially straight.

16. A method as claimed in any one of claims 13 to 15 wherein each segment is identical.

17. A method as claimed in any one of claims 13 to 16 wherein the sacrificial anode is cylindrical, square, rectangular or segmental, and is composed of between two and six segments.

18. A method as claimed in any one of claims 13 to 17 wherein each segment is formed by continuous casting.

19. A method as claimed in claim 18 wherein each segment is forcibly cooled.

20. A method as claimed in claim 19 wherein the cooling is effected by water.

21. A method as claimed in claim 20 wherein the casting is effected by direct chill casting.

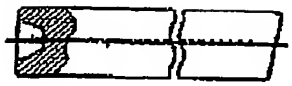
22. A method as claimed in any one of claims 13 to 21 wherein the sacrificial material is magnesium or a magnesium alloy.

23. A method as claimed in claim 22 wherein the sacrificial material is an alloy consisting essentially of magnesium and from 0.15% to 1.3% by weight of manganese.

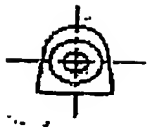
24. A method as claimed in claim 13 substantially as hereinbefore described.

25. A sacrificial anode produced by a method as claimed in any one of claims 13 to 24.

Figure 1

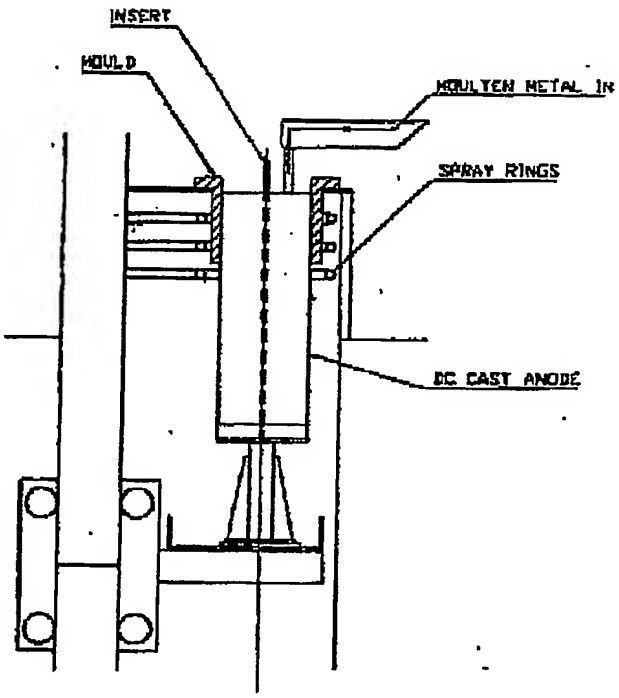


Side View



End View

Figure 2



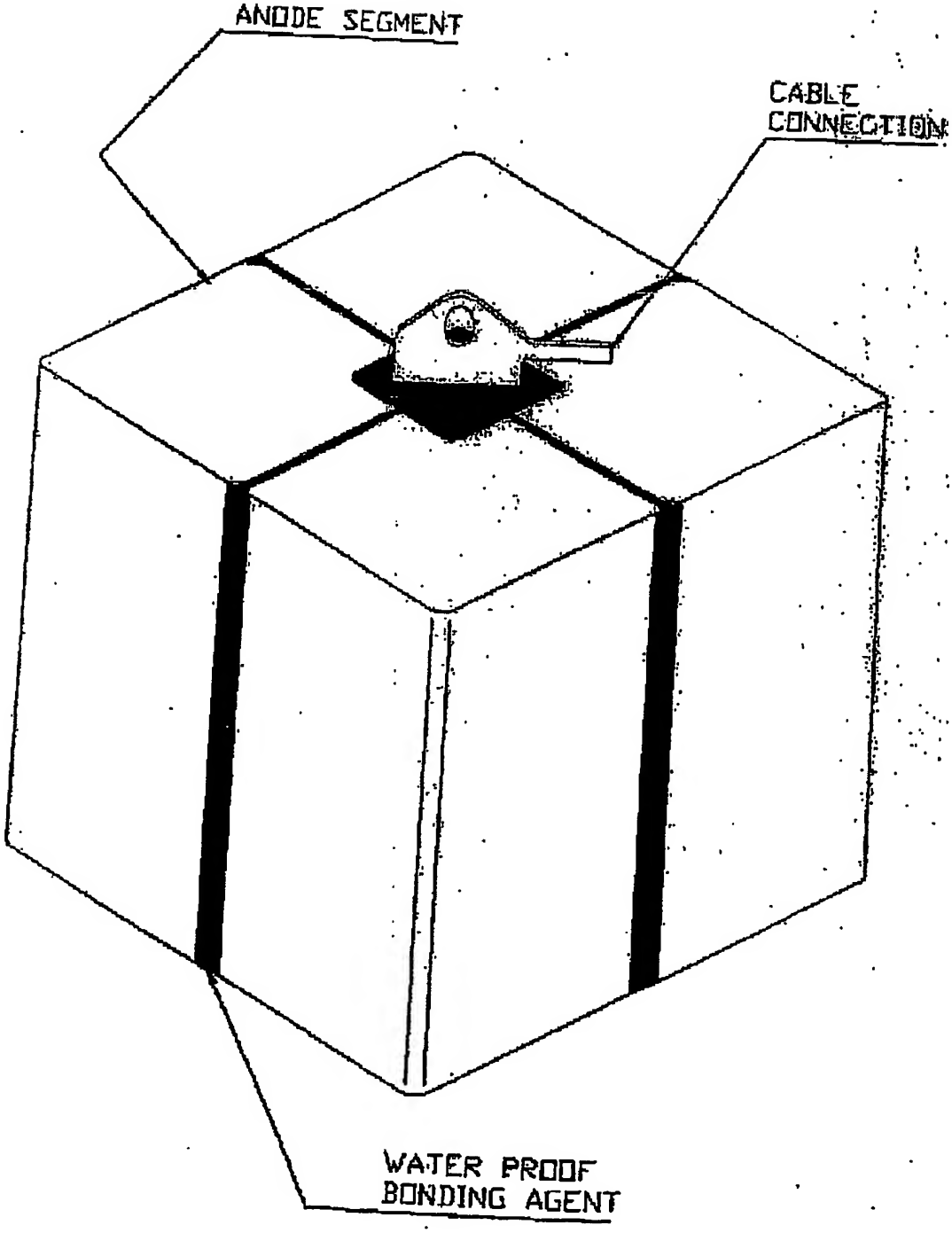


Figure 3